Utility Patent Application

<u>CONFIDENTIAL INFORMATION</u>

TURBINE GENERATOR VIBRATION DAMPER SYSTEM

<u>RELATED APPLICATIONS</u>

15   There are no previously filed, nor currently any co-pending applications, anywhere in the world.

<u>BACKGROUND OF THE INVENTION</u>

<u>1. Field of the Invention</u>

20   This invention relates to the methods and apparatuses for active removal internal vibrations from turbine-generator-sets (T-G-S). This invention covers all possible variations of horizontally placed T-G-Ss (in size, capacity, working velocity of rotor, diameter of working wheel, etc.), also all reasonable values of vibration (in amplitude and frequency, etc.), at presently existing all types power

25   electro and other plants using rotary machines. Also, if the designs of future turbines and generators, first of all of high capacity, could originally include their

bearings-fulcra improvements, based on this invention [use of the specified

bodies, the B-F-L-Ws], that will make such machinery - - with minimized

shutdown period and minimized operating vibration - - both more efficient and

more safe for customers.

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2. Description of the Related Art

From the beginning of time, mankind has relied on various sources of

energy to survive. These sources have included wood, coal, oil, wind power, and

nuclear energy to just name a few. However, just about all these sources rely on

10   the fact that mechanical movement is transformed into electrical power by a

turbine-generator-set. While the overall design of these turbine-generator-sets

has been improved over the years, they still must deal with internal vibrations.

Most of these vibrations are engineered or machined out during manufacture,

but additional vibrations develop as the machine operates throughout the years.

15   When these vibrations reach an unacceptable level, the turbine-generator-set

must be shut down to allow adjustments to take place. These adjustments not

only take time and money to perform, but the generator is not online, thus no

electricity or associated revenue is produced. Accordingly, there exists a need for

a means by which vibrations can be reduced in a turbine-generator-set in a

20   continuous manner without the requirement of taking the generator off-line. The

development of the Turbine Generator Vibration Damper System fulfills this

need.

The Turbine Generator Vibration Damper System, as its name implies, is an apparatus that actively removes internal vibrations from turbine-generator-sets. The invention relies on dynamic forces generated by a pair of "wings" and

5   associated hardware mounted on the bearing housing, which operate to offset internally produced vibrations in an active or "real time" fashion. This is in contrast to the typical method of taking the turbine-generator off-line, shutting it down and then eliminating the source of vibration. The invention allows the generator to remain operational during adjustments. Thus, it remains on-line

10   producing electricity and associated revenue. Additionally, the workers, material and labor normally used in the static reduction of vibration are saved as well. As a net result, less redundancy or backup sources of electricity are needed. The use of the Turbine Generator Vibration Damper System provides a real solution to internal vibrations that develop in turbine-generator-sets throughout their

15   lifetime.

A search of the prior art did not disclose any patents that read directly on the claims of the instant invention; however, the following references were considered related:

U.S. Patent No. 6,070,704, issued in the name of Sasse, describes a

20   torque converter with a torsional vibration damper.

U.S. Patent No. 6,298,965, issued in the name of Krause et al., describes

a force transmitting apparatus having an external damper.

U.S. Patent No. 6,112,869, issued in the name of Krause et al, desribes a force transmitting apparatus having an external damper.

U.S. Patent No. 6,471,484, issued in the name of Crall, describes a
5   method and apparatus for damping rotor assembly vibrations.

U.S. Patent No. 6,006,879, issued in the name of Sudau, discloses a torque converter with a torsional vibration damper arrangement.

U.S. Patent No. 6,056,093, issued in the name of Hinkel, describes a torque converter with a turbine shell integrated with a torsional vibration damper.

10   U.S. Patent No. 6,056,092, issued in the name of Hinkel, describes a torque converter with bridge coupling and vibration damper between bridge coupling and turbine hub.

And, U.S. Patent No. 6,102,174, issued in the name of Sasse, describes a hydrodynamic torque converter with a torsional damper arranged in the inner torus.

15   Consequently, a need has been felt for providing an apparatus and method for removing turbine generator vibrations without necessitating the shutdown of such turbine generators.

SUMMARY OF THE INVENTION

20   Vibration at rotary machines is what designers want least. Still, a beyond-normal vibration is the major problem causing unexpected emergency stops of a

rotary machinery all over the world. In methods of removal of a beyond-normal vibration at turbine-generator-sets, it is known to shut these sets down into a short- or long-time stop, depending on the volume of work of vibration removal operation. In this invention, removal of vibration does not require a T-G-S to be shut down: its

5   operating, and generating electricity and associated revenue, is continuing within process of removal of vibration.

According to the present invention, removal of vibration is accomplished by a summary action of both massive-loading and self-exciting forces, issued from Bearing-Fulcrum-Load-Wings [B-F-L-W], that are attached at extreme points, in

10   where vibration is resulted upon T-G-Ss.

Installed either in advance or within process of operation of the T-G-Ss, the B-F-L-W's serve the following purposes:

1.   To follow scanningly any change of vibration situation upon the bearings, with damping any slight increase of vibration, being indicated there as beyond-normal, down to normal values for all the processes

15   of T-G-Ss operation /starting, all common-mode (power) operations, stopping/ thoroughly, and, therefore, keeping a complete vibration situation upon T-G-Ss permanently normal;

2.   To prevent an increase of vibration without stopping operation of turbo-

20   aggregate, and thereby prevent any vibration from growing; and

3.   To damp beyond-normal vibrations, that may occasionally occur within

common-mode operations of the T-G-S's.

All of these avoid unexpected stops experienced presently at power, chemical and other industries that result from T-G-Ss throwing down into beyond-normal vibration situations and/or to prolong T-G-Ss being in operation / generating

5   electricity up to their planned stops or up to other connected machinery/equipment stops, within which removal of vibration at these T-G-Ss may be done by other methods of adjustment.

In operation, the present invention relates to methods and apparatuses for removal, in wide in super-wide diapasons, of beyond-normal vibrations that may

10   occur at horizontally placed turbine-generator-sets [T-G-Ss] within period of the time of their starting or/and current (common-mode) operations processes.

The key places of control of the vibration situation are presently the bearings of turbine-generator-sets. Any disbalance impulses or pulsations inside the cylinders, disturbances leading to vibration, are transferring eventually to influence

15   on vibration situation at the bearings as fulcra of the rotors.

Increase of vibration at a bearing results into destroying of its lubricant layer, that results into a local increase of temperature of cooling oil (or cooling agent), and, therefore, into increase of temperature of babbitt-layer (or slippery surfaces) of a bearing.

20   When temperature of cooling oil (or cooling agent) inside a bearing is reaching upto the critical level, an automatic control system of turbine-generator-set

is giving the signal 'STOP' to shut down this set on the whole, or this set may be

stopped by operator before or within the temperature of oil has reached the critical

level.

Destroying of slippery surfaces in such bearing results into destroying of the

5   bearing(s), the rotor neck surfaces, etc., and may eventually lead to destroying of

blade apparatus of the rotor and the correlative stationary parts in the cylinder.

All parameters taken from the bearings of a turbine-generator-set are determining

and forming the basic signal to shut down the set in case of a beyond-normal

vibration.

10   Nevertheless, presently practicing methods of removal of a beyond-normal

vibration at T-G-Ss, that occures within its starting or/and common-mode operations

processes, have a concern with the zone(s) of the rotor(s) muff(s), but not

bearing(s).

According to presently practicing methods, removal of vibration is conducted

15   by balancing the rotor(s) within the zone(s) located at the(se) rotor(s) muff(s) – the

nearest muff(s) to the bearing(s) with an indicated beyond-normal vibration.

It is common that this balancing includes loading (with the small bodies –

special weights of known mass – in the specially calculated place on a body of the

rotor half-muff) or/and unloading this half-muff in the special place on its body.

20   Loading is ordinary carried out by fixing the weight(s) (with welding, joining, etc.) on

a body of the rotor half-muff. Unloading is ordinary carried out by cutting the

weight(s) (or picking, burning, hollowing, glooving, etc. the weight(s) or body metal) off a body of the rotor half-muff.

To conduct this safely and according to the presently existing methods, two general things are required:

5   a)   the covering case(s) of the rotor(s) half-muff(s) has/have to be open to reach the body of the muff(s), and/or, therefore,

b)   this turbine-generator-set has to be shut down, stopped in operation, and, therefore, not generating electricity (or compressing, or pumping products).

As minimum, the construction of all the(se) muff(s) covering case(s) (and of

10   other parts) at all presently existing and the future turbine-generator-sets will require the preliminary and/or in-service changes to be done in a way to readily conduct these methods [in any bearing vibration occasion at any of turbines, generators, compressors or pumps] without stopping turbine-generator-sets.

However, if the decision to stop the set for balancing the rotor(s) at the

15   muff(s) zone(s) is taken [or, more often, if the T-G-S has already been stopped automatically], then this stop also, commonly and as minimum, includes

1.   Shutting down the set [turbine-generator].

2.   Opening the bearing(s) of a beyond-normal vibration. Inspection the surfaces of babbitt layer inside the bearing(s) and the rotor(s) neck

20   surfaces. Closing the bearing(s).

3.   Opening the upper carter(s) of the case(s) of the rotor(s) muff(s).

4.   Control of the rotors gathering in the place of their junction.

5.   Loading the muff(s) body/(ies) with the balancing weights or removing

(extraction) the balancing weights off the muff(s) body/(ies): balancing

the rotor(s).

5   6.   Dynamic balancing of the rotor(s). Testing within starting, gradually

loading power, and stopping the set.

7.   Closing the carter(s) of the case(s) of the muff(s).

8.   Starting the set in operation.

10   Eventually, it results into loss of operating time from hours to days per year

for the set, and into loss of money upto millions of dollars per year for the set (due to

non-generating electricity, in case of power plants).

The new places (the new zones) of application to remove vibration at T-G-S.

In this invention the place of application is transferred from the zone(s) of muff(s) to

15   the zones of bearings-fulcra of T-G-Ss, i.e. where vibration is resulted.

Zones for application of the process (the method of removal of beyond-

normal vibrations at T-G-Ss without stopping their generating electricity / being in

operation) are shown in Fig. 1.

One can see that now the zone of application is transferred to the bearing-

20   fulcrum zone(s) of the bearing(s) with indicated beyond-normal vibration.

An advantage of the presnet inventoin is that removal of vibration does not

require a T-G-S to be shut down, thereby continuing operating and generating

electricity during the process of removal of vibration.

Another advantage of the present invention is that ic can be installed in

advance, or within process of operation of T-G-Ss, the B-F-L-Ws.

5   Yet another advantage of the present invention is that it is capable of

damping beyond-normal vibrations that may occasionally occur within common-

mode operations processes upon operating T-G-Ss, and, so, improving a thorough

safety of T-G-Ss and their efficiency.

10   BRIEF DESCRIPTION OF THE DRAWINGS

The advantages and features of the present invention will become better

understood with reference to the following more detailed description and claims

taken in conjunction with the accompanying drawings, in which like elements are

identified with like symbols, and in which:

15   FIG. 1 is a cross sectional elevational view of a turbine generator vibration

damper system according the present invention, showing zones for application of

the process (the method of removal of a beyond-normal vibrations at T-G-Ss without

stopping their generating electricity / being in operation) -- bearings-fulcra zones;

FIG. 2A is a front elevational view of a principal scheme of application of the

20   present invention upon presentintly existing T-G-Ss;

FIG. 2B is a front elevational veiw of a principal scheme of application of the

present invention upon newly designed T-G-S's incorporating the present system

integrally therein;

FIG. 3 is a front elevational view of a Bearing-Fulcrum-Load-Wings [B-F-L-W]

for removal of beyond-normal vibrations in wide diapasons;

5   FIG. 4 is a front elevational view of a B-F-L-W for removal of beyond-normal

vibrations in super-wide diapasons;

FIG. 5 is an exploded perspective view showing the main elements of the B-

F-L-Ws;

FIG. 6 is a perspecitve view of the B-F-L-Ws for removal of beyond-normal

10   vibrations in wide diapasons;

FIG. 7 is a pespective view of the B-F-L-Ws for removal of beyond-normal

vibrations in super-wide diapasons;

FIG. 8 is a perspective view of the B-F-L-Ws for removal of beyond-normal

vibrations in super-wide diapasons showing placement in direction perpendicularly

15   to rotor axis of T-G-S;

Fig. 9 is an elevational view depicting loads of the B-F-L-Ws in various

embodiments;

FIG. 10 depicts varous configurations for the wings of the B-F-L-Ws;

FIG. 11 is an exploded cross sectional elevation of fixture units for fixing

20   loads of the B-F-L-Ws to a case of bearing-fulcrum;

FIG. 12 is a side elevational view of the preferable setting of fixture units of

the B-F-L-Ws.

FIG. 13 is a perspecitve view of the installation of the B-F-L-Ws with fixation which not requires replacement of the standard bolts of bearing-fulcrum;

FIG. 14 is a pespective view showing variants of units for changing the length

5   of wings of the B-F-L-Ws;

FIG. 15 is elevational views of various types of drivers (shown schematically) of units for turning wings of the B-F-L-Ws;

FIG. 16 is a perspective view of a change of mass of wing of the B-F-L-Ws by attached weights;

10   FIG. 17 depicts side elevational views of variants of joint-units of the B-F-L-Ws;

FIG. 18 is an exploded view of the operations (in number and sequence) to install the B-F-L-Ws;

FIG. 19 depicts placements of the B-F-L-Ws around bearing-fulcrum of T-G-S

15   in direction parallelly to rotor axis;

FIG. 20 depicts both correct and incorrect placements of the B-F-L-Ws at bearing-fulcrum /if to follow the instructions of the B-F-L-Ws method;

FIG. 21 depicts placement of the B-F-L-Ws upon bearing-fulcrum at T-G-S in direction perpendicularly to rotor axis;

20   FIG. 22 is a graph for determination of initial single mass of the load-wing of B-F-L-W as function of diameter of the rotor neck of T-G-S;

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FIG. 23 depicts graphs for determination of initial single mass of the load-wing M(L-W)min as function of diameter of the rotor neck dneck rotor, for various values of designed operating frequency f of T-G-Ss;

FIG. 24 depicts distribution of the minimal / initial / single mass of the load-

5   wing M(L-W)min among all elements and mechanisms, forming the single bearing-fulcrum-load-wing (B-F-L-W);

FIG. 25 depicts distribution of the minimal /initial/ single mass of the load-wing M(L-W)min among all elements and mechanisms, forming the single bearing-fulcrum-load-wing (B-F-L-W);

10   FIG. 26 depicts distribution of the minimal /initial/ single mass of the load-wing M(L-W)min among all elements and mechanisms, forming the single bearing-fulcrum-load-wing (B-F-L-W) with placement of the B-F-L-Ws in direction perpendicularly to rotor axis;

FIG. 27 depicts connecting of computer with the database to the bearing

15   vibrations indicatory system to conduct removal of beyond-normal vibrations at the bearing-fulcrum automatically;

FIG. 28 depicts alternate methods of damping vibration;

FIG. 29 depicts automation of process of removal of beyond-normal vibrations at T-G-Ss utilizing computer control;

20   FIG. 30 is an alternate process of FIG. 29 depicting variants of sending signal "α";

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FIG. 31 depicts automation of process of removal of beyond-normal

vibrations at T-G-Ss for super-wide diapasons;

FIG. 32 depicts automation of process of removal of beyond-normal

vibrations and keeping vibration situation normal and stable at whole T-G-S by the

5   use of computer system and automatic equipment;

FIG. 33 depicts simple wings of the B-F-L-Ws for appplications for

damping vertical, transverse, axial, complex vibrations within its turn round from

0° to 90°;

FIG. 34 is a graphical representation showing an increase of damping

10   capabilities (in damping momentum Mdamp. and damping amplitude Adamp.) of

wing depending on elongation of its length;

FIG. 35 depicts folding wings of the B-F-L-Ws;

FIG. 36 depicts additional damping capabilities of wing depending on its

flexibility;

15   FIG. 37 depicts variants of the forms of the B-F-L-Ws adapted to be used

at the T-G-Ss' bearings-fulcra within limited space for spreading the wings;

FIG. 38 shows correlations A' and B' -- in mutual dimensions and

constructions -- between bearings and their related rotor cylinder for which the

method of removal of vibrations may be used so, that the B-F-L-WS will be

20   installed already upon whole rotor cylinder;

FIG. 39 depicts variants of installation of the B-F-L-Ws upon the whole

rotor cylinders;

FIG. 40 shows a side elevational view of the specified rotor cylinders of the T-G-S as the fulcra of the whole rotor system;

FIG. 41 is a persective view showing variants of simple changings of the

5   construction of bearing(s)-fulcrum (or the form of its upper cover) in the future designed T-G-Ss to be adapted for use of the B-F-L-Ws method -- removal of vibrations at T-G-Ss without stopping their generating electricity / being in operation;

FIG. 42 is a perspective view showing removal of vibrations with the B-F-

10   L-Ws at bearing-fulcrum of T-G-S. Wind Electro Power Plant;

FIG. 43 is a perspective view showing removal of vibrations with the B-F-L-Ws at bearing-fulcrum of T-G-S. Hydro Electro Power Plant;

And, FIG. 44 is a perspective view showing removal of vibrations with the B-F-L-Ws at whole T-G-S.

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DESCRIPTION OF THE PREFERRED EMBODIMENTS

The best mode for carrying out the invention is presented in terms of its preferred embodiment, herein depicted within the Figures.

1. Detailed Description of the Figures

20   According to the preferred operation, the preseint invention relies on dynamic forces generated by the B-F-L-Ws, which operate to offset internally

produced vibrations in an active or "real time" fashion. As seen best in FIG. 2A-2B, it can be seen that the static and dynamic components that would form the Turbine Generator Vibration Damper System include the loads 101 and the wings 102 that may be simple or changeable in length, width, weight, folding, multiply, etc. The fixture units for fixing the loads to the case of the bearing-fulcrum 103 and the fixture units for fixing the wings to and turning the wings around the load 104 (or to the joint-unit) utilize connecting arm 105. It may also include, the loads, the wings and analogous associated mechanisms for damping of vibrations in the direction of the rotor axis, if necessary.

Damping of vibrations may be done with manual changing of the operational parameters of the vibrations damping or/and automatically by use of of automatic equipment and computer system. The Turbine Generator Vibration Damper System may be installed at presently operating T-G-Ss, as shown in FIG. 2A, and in future designed T-G-Ss where the features of the bearing housing will be changed correspondingly for use of this method, as shown in FIG. 2B. Parameters V, T and A are current vertical, transverse and axial vibrations at the bearing.

As shown in FIG. 3 and 4, more details on parameters α and L, indicated in Fig. 2A. The principal scheme of the B-F-L-Ws for removal of vibrations in wide diapasons is shown in Fig. 3 . Here, for the stated mass of the load M and length of the wing L, also for the stated mass of the wing m and possible

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additional weight w, tuning the system to the damping of vibrations is done by

changing the angle α. Principal scheme of the B-F-L-Ws for removal of

vibrations in super-wide diapasons is shown in Fig. 4 For the stated mass of the

load M, also for the stated mass of the wing m and weight w, tuning the system

5   to the damping of vibrations is done by changing the length of the wing L and the

angle α.

As earlier indicated, the system foresees the change of width, weights,

etc. of the wings as well, if it would be necessary.

Principal view with indication of the main elements of the B-F-L-Ws,

10   installed at the bearing-fulcrum of T-G-S, is shown in Fig. 5.

Here it includes: Loads, Wings, Fixture units, Units for turning the Wings

(see: A), Units for changing the length of the Wings (see: B) and Joint-Unit.

When, by all means, the final design (construction) of the B-F-L-Ws will

eventually be, as designed, completed following the tests, it would be further

15   reasonable to use Fig. 6 for illustrative purposes in the detailed description of this

invention.

As above indicated, this invention covers all possible ways of designing,

manufacturing, assembling, fastening, calculating the parameters, testing and

using of the B-F-L-Ws and the computer system beyond those described below

20   in this Specification unless the results of the work of the Turbine Generator

Vibration Damper System are positive, i.e. it provides a solution to internal

vibrations that develop in turbine-generator-sets throughout their lifetime.

This invention covers all possible variety of the B-F-L-Ws, which may be used within this method at presently existing and operating T-G-Ss and at the T-G-Ss of the future design. It also covers all possible variants of changes that may

5   be done in the T-G-Ss bearings (or in the bearing-fulcra) of the future design at the future T-G-Ss in accordance with this invention.

The drawings, as described, are not of the final design (as the final design is to be obtained following the tests) but of the schematical design, that is sufficient, however, for detailed description of how the Turbine Generator

10   Vibration Damper System may work for various applications upon T-G-Ss. Use of various elements and details of the B-F-L-Ws with placement in various directions to the rotor axis of T-G-S, including those with the space constraint and upon the whole rotor cylinders, of preferable placements and fixations of the B-F-L-Ws, of variations of automation of process, etc. is to be offered to

15   manufacturers and customers. Being preferable, they are, however, not mandatory for as long as all other possible B-F-L-Ws and associated computer systems within frames of this invention are hereby covered when they may still provide a solution to internal vibrations under observation of the Limitations of this invention.

20   Referring to FIG. 6, a detailed variant of the B-F-L-Ws, installed at the bearing-fulcrum of T-G-S, for removal of beyond-normal vibrations in wide

diapasons is shown. This variant of B-F-L-W's include: Loads (101), Wings (102), Fixture units (103), Joint-Units (104) and Unit for turning the Wings (105). Detailed variant of the B-F-L-Ws, installed at the bearing-fulcrum of T-G-S, for removal of vibrations in super-wide diapasons is presented in Fig. 7.

One can see that this variant of the B-F-L-Ws includes: Loads (101), Wings (102), Fixture units (103), Joint-Units (104), Units for turning the Wings (105) and Units for changing the length of the Wings (106). At the end of the wing one can also see Unit for changing the Weights.

Detailed variant of the B-F-L-Ws, installed at the bearing-fulcrum of T-G-S, for removal of vibrations in super-wide diapasons in the direction perpendicularly to rotor axis of T-G-S is shown in Fig. 8. In general, every B-F-LW, named hereinafter as *the single B-F-L-W*, may consist of the following elements:

1.   The load, which may be casted as a whole body, if designed, or, as shown, assembed from the parts. An assembling must form the load as a rigid body. See more details in 9.

2.   The wing, which may be formed (casted) as a whole body, if designed, or assembled from the parts as shown. See more details: Figs. 10, 35.

3.   The fixture unit for fixing the wing to and turning the wing around the load (or to the joint-unit). It may be of any suitable construction. See more details: Figs. 10, and FIG. 17(par. 4).If designed, the wing may be formed together with

(the part of) the load.

4.   The fixture unit for fixing the load to the case of the bearing-fulcrum.

It may be of various [of any suitable] constructions, but here [see: Fig. 11 (A),

(B), (C)] as example, shown variant of using a pair of special pins and nuts.

5   For preferable setting of fixture units, see Fig. 12. For variant of installation of the

B-F-L-Ws with fixation which not requires replacement of the standard bolts, see:

Fig. 13.

The single B-F-L-W may also include:

10   5.   The unit for changing the length of wing (lengthening). See: Fig. 14. As

earlier indicated, there might be the unit for changing the width of wing as well.

6.   The unit for changing the weight of wing (weightening). See: Fig. 16.

The whole B-F-L-W needs

15   7.   The unit(s) for connecting the single B-F-L-Ws together – the joint-units of

the B-F-L-Ws. See: Fig. 17.

8.   The computer system. See more details: Figs. 27 and 29-31.

In reference to all the various embodiments, the loads 101 can comprise

20   many possible types and at least fourteen various forms of the loads of the B-F-

L-Ws are presented in the Figures. The ways (variants) of forming the loads of

the B-F-L-Ws are also shown. The wings 102 can also come in various forms. Variants of fixation the loads to the wings are also shown. For preferable fixations of the wings fulcra (on)to the loads and the joint-units, see also: Fig. 17 (par. 4a, 4b, 4c). For variants of folding wings, see: Fig. 35.

5   Fixture units 104 are for fixing the loads of the B-F-L-Ws to a case of bearing-fulcrum. Variants of the fixture units for fixing loads of the B-F-L-Ws to a case of bearing-fulcrum are shown in Fig. 11. It may be in form of not divided pin (A) or bolt-collector and pin (B), (C). If such units will be installed, in advance or within operation of T-G-S, instead of the the standard bolts of the bearing-

10   fulcrum, an installation of the B-F-L-Ws at the bearing-fulcrum may take just some minutes only

The preferable setting of fixture units is shown in Fig. 12. Variant of installation of the B-F-L-Ws with fixation which not requires replacement of the standard bolts of bearing-fulcrum is presented in Fig. 13. Units for changing the

15   length of the wings of the B-F-L-Ws, and variants of the units for changing the length of the wings of the B-F-L-Ws are shown in Fig. 14. The electrically driven units are presented on this picture.

Units for turning the wings of the B-F-L-Ws can use various types of drivers (shown schematically) of units for turning the wings of the B-F-L-Ws are

20   presented in Fig. 15. Here one can see hydraulically (electro-hydraulically) driven wings (1), electrically driven wing (2), mechanically (manually) driven wing (3),

electro-mechanically (and manually) driven wings (4), (5), (6).

Units for changing the weight of the wings of the B-F-L-Ws are shown in Fig. 16, which indicates variant of changing the weights w1, w2 and w3 by changing length and/or diameter of the weights.

5   Various kinds of the joint-units of the B-F-L-Ws are shown in Fig. 17. Variant 1 presents the connecting plates (also bars, ribs, etc.) that may serve to firmly join two loads. Variant 2 indicates the types of the connecting arch-shaped units for joining loads together. Here, for variants 2b, 2c and 2d wings fulcra are shown as fixed onto the joint-units. Variants 2e and 2f present the detailed view

10   of the connecting arch-shaped pipe units. Variants 3a and 3b show the constructions when two loads may be manufactured as the whole one (by casting, pressing, shaping, etc.) with the arch jointing. For variant 3b wings fulcra are shown as fixed onto the joint-unit. One can also see the views of mechanisms for turning the wings of the B-F-L-Ws, shown in Fig. 17 with fixation

15   (on)to the loads or onto the joint-units.

The most preferable variants of fixation of wings fulcra (on)to the loads and the joint-units are shown in Fig. 17 (par. 4a): those are the variants when the wings fulcra are fixed without eccentricity to the axises of the fixture units for fixing the loads to a case of the bearing-fulcrum of T-G-S (for the view

20   perpendicularly to the axis of the bearing-fulcrum of T-G-S).

Pictures 4b and 4c in Fig. 17 describe what can happen if the wings of the

B-F-L-Ws are fixed with the eccentricity to the axises of those fixture units.

There are some recommendations given for designing the joint-units and correct

fixing the wings (on)to the loads and the joint-units. First of all, designer should

be tending to obtain the value of the external a and/or internal e eccentricities as

little as possible to avoid the bending momentums in the joint-units. Second, the

wider diameter b_1 of the fixture units is the better one, and the eccentricity (if

any) a_1 should be less than $b_1/2$ (see: Fig. 4h, par. 4b). Third, in case of internal

eccentricity (such as for the B-F-W-Ss working in the limited space) the shorter

wings are preferable (see: Fig. 17, par. 4c). Fourth, the system formed out of the

loads M, the fixture units d and the joint-units R_1, R_2, should be so rigid that it

may resist the momentum originated from the eccentricity (if any) (see: Fig. 17,

pars. 4b, 4c).

As shown in FIG. 18, s the order (in number and sequence) to install - - to

place and to fix - - the B-F-L-Ws at the bearing-fulcrum of T-G-S. This variant of

installation includes:

1.   Install 4 fixture units A (instead of the standard bolts of the case of

the bearing-fulcrum). The parameters of the fixture unit A should be equal to (or

better than) the corresponding parameters of the standard bolts. The installation

of the fixture units A may be done in advance or within operation of the T-G-S. It

may be done at one or several, or all bearings-fulcra of the T-G-S.

2.   Place the B-F-L-Ws on the fixture units A. One should use a crane

or lifting mechanism for this operation. Join the pins B with the fixture units A. And

3.   Tighten the nuts D and E of the B-F-L-Ws.

5   Most adequate and practically possible variants of placement of the B-F-L-Ws around bearing-fulcrum of T-G-S in direction parallelly to rotor axis are presented in Fig. 19. Here, the most adequate and practically possible variant is (1 & 1'). Most adequate variant of placement is (4). Variants (2 & 2'), (3 & 3') and (6 & 6') may be considered additional (and limited in use).

10   Correct and incorrect placements of the B-F-L-Ws at bearing-fulcrum are shown in Fig. 20. One should pay attention to that transferring of vibrations from/to the case of bearing-fulcrum should be done through the zones of junction the B-F-L-Ws with the case of bearing-fulcrum, but not directly through the covering case(s) of bearing (for the view perpendicularly rotor axis) (see: Fig. 20,

15   2 Correct placement). Please also look at Fig. 12.

Most adequate and practically possible variants of placement of the B-F-L-Ws upon bearing-fulcrum of T-G-S in direction perpendicularly rotor axis (e.g. upon an axial stress bearing-fulcrum) are presented in Fig. 21. One can see that the most adequate and practically possible variant is (1), and most adequate

20   variant is (2). Variant (3 & 3') may be considered additional.

2.   Operation of the Present Invention.

When the B-F-L-Ws are being assembled, the complete tests are being passed and the data is collected, then being installed at the bearing-fulcrum the B-F-L-Ws may be operated by operator manually. Depending on whether the

5   vibrations will be damped in wide or super-wide diapasons, operator should (manually or with the use of mechanisms) change the angles α, or the lengths of the wings L and corresponding angles α, according to the collected data for the vibrations being damped.

It is perferred that those operations will be done by automatic equipment

10   with use of computers. Connecting of computer with the database to the bearing vibrations indicatory system to conduct removal of beyond-normal vibrations at the bearing-fulcrum automatically is shown in Fig. 27. Other methods of damping vibration are shown in Fig.28. The data taking devices of the current vibrations are practically installed at the bearings at all industrial T-G-Ss.

15   Those electronic devices are indicating vertical, transverse and axial vibrations at every bearing of T-G-S. When computer with the installed database (see above: Collecting the data) is connected with the bearings vibration indicatory system, the values of vibrations will be received in computer and compared with what is in the database according to the tests of the B-F-L-Ws (see: Fig. 29- automation -- by use

20   of computer and automatic equipment -- of process of removal of beyond-normal vibrations at T-G-Ss in wide diapasons).

By way of illustrations, if the values of current vibrations at the bearing-fulcrum are: vertical V = 14 μm, transverse T = 9 μm and axial A = 1 μm. (The upper limits of normal limits of vibrations: V, T = 12 μm; A = 1 μm. The permissible limits: V, T = 20 μm; A = 5 μm.) Among the tested analogous

5   situations, for this situation the angle α should be changed up to 81° to damp the beyond-normal vertical vibration. Computer gives signal "α = 81°", which goes to the executive mechanism that turns the wing upto 81°: the beyond-normal vibration is damped. The signal α, being sent from the computer to the executive mechanism(s) (see Fig. 30) may be bifurcate (variant I) or sole (variant II). For

10   variant I: bifurcate signal sent equally to the two separate executive mechanisms for turning the wings of the B-F-L-Ws. For variant II: sole signal sent to the united executive mechanism for turning the wings of the B-F-L-Ws.

Automation of process of removal of beyond-normal vibrations at T-G-Ss in super-wide diapasons is shown in Fig. 31. Computer system works

15   analogously to what is described in Fig. 32. But now, for the received and compared values of vibrations, computer sends two signals [L and α], to the executive mechanisms to damp beyond-normal vibration. Here, an optimizer may be used in this process: it is device serving to choose the variant of (L & α) - - among many such sets of values for the one, which is the nearest [in time and

20   to the values currently determined] set of (L & α) - - to minimize work for the elongation and turning the wings in vibrations damping. Block for α averaging

(see Fig. 29) and L and α averaging block (see Fig. 31) are devices that may be

used for averaging of the values of α (Fig. 29) and the values of L and α (Fig. 30)

among numerous currently obtained within certain very short period of time.

Automation of process of removal of beyond-normal vibrations and

5   keeping vibration situation normal and stable at whole T-G-S by the use of

computer system and automatic equipment is presented in Fig. 32. Here,

analogously to above-described automation of vibrations damping at one

bearing-fulcrum, vibrations are damped at all the bearings of the whole turbine-

generator-set, i.e. at the bearings-fulcra of all cylinders simultaneously, following

10   scanningly any change of vibration situation upon the bearings, with damping

any slight increase of vibration, being indicated there as beyond-normal, down to

normal values for all the processes of T-G-Ss operation; this will keep a

complete vibration situation permanently normal and stable at the whole T-G-S.

It should be noticed, that here every B-F-L-Ws receives its own command from

15   the computer (computer system).

Automation of process of removal of beyond-normal vibrations at T-G-Ss

may be done when the B-F-L-Ws are installed at the whole cylinders

One can see in Fig. 33 how vibration damping capabilities of simple wings

increase within wing's turn round from 0° to 90° for damping of vertical a),

20   transverse b) and axial c) vibrations. Here two variants of the B-F-L-Ws for

damping of a complex vibration, i.e. of vertical, transverse and axial vibrations

simultaneously, are also shown.

An increase of damping capabilities (increase of damping momentum Mdamp. and damping amplitude Adamp.) of wing depending on elongation of its length is shown in Fig. 34. One can see that for the same operating frequency both the damping amplitude and the damping momentum will increase with elongation of the wing. As a variant of how an elongation of the wings may also be achived, one can see picture of use of the folding wings that may allow increasing of the damping amplitude and the damping momentum of the wings in Fig. 35. Here, pictures a), b), c) and d) show variants of spreading the folding wings. Variant of the mechanism for turning the folding wing is shown in picture e).

When spreading of folding wings (or even spreading of simple wings) in the operating space is limited, an increase of damping capabilities of the B-F-L-Ws may certainly be done by placement of two or several simple wings (e.g. the heavy and short wings) with their fixation (on)to the loads or/and the joint-units *one under another* as shown in Fig. 17 (par. 4a). For that the air space(s) between the wings must allow them not touch each other within turn of each wing from 0° to 90° when the turn is done simultaneously with other wings.

Pictures of additional damping capabilities of wing depending on its flexibility are presented in Fig. 36. Use of highly elastic, flexible (in construction, substance or texture of material) wings may change the damping capabilities of

the wing, comparing with use of firm and non-flexible one. Some variants of the

forms of the B-F-L-Ws adapted to be used at the T-G-Ss' bearings-fulcra within

limited space for spreading the wings are presented in Fig. 37. They relate, first

of all, to the bearings-fulcra which are not completely open at some types of T-G-

5   Ss. Variant A shows the B-F-L-Ws with the wings which work is based on the

principle of work of the folding wings. Variant B shows the B-F-L-Ws where

fixation of the wings boxes (with the wings) onto the joint-unit is done closer to

the rotor vertical axis.

Under certain conditions, the rotor cylinders themselves may be accepted

10   as the bearings-fulcra of the whole rotor system of the complete turbine-

generator-set. Then the B-F-L-Ws may be installed at those cylinders

(analogously to how it is done at bearing-fulcrum of cylinder of T-G-S) to damp

beyond-normal vibrations at the rotor cylinders and keep a complete vibration

situation over the whole rotor system at the whole T-G-S stable and normal

15   permanently.

One may use this method in the only way, when the B-F-L-Ws will be

installed at the whole rotor cylinders, if only those rotor cylinders are of the type

(in the size, the construction, etc.), where

(a)   the related indicated vibrations at the bearings at the whole rotor

20   cylinder will not differ from each other, or will differ in the certain stable functional

mutual dependence which is /or is enable to be/ known (or determined by

present methods) for every moment; and at the same time; and

(b)   the removal of beyond-normal vibrations by this method can surely

be done reducing the related vibrations down to normal level simultaneously both

at the whole rotor cylinder (and at all its internal parts) and at its rotor bearings in

5   particular.

Those cylinders are named as the specified rotor cylinders. Correlations

A' and B' - - in mutual dimensions and constructions - - between bearings and

their related rotor cylinder for which the method of removal of vibrations may be

used so, that the B-F-L-Ws will be installed already upon whole rotor cylinder are

10   shown in Fig. 38. Here, as examples, are given variants when the size of the

bearing (in diameter) of the T-G-S does not differ from (or approximately equal

to) the size of cylinder itself (in diameter) (see: Correlations A... A'), or/and when

the distance between the bearings along the rotor axis does not differ from (or

approximately equal to) the length of the cylinder itself (see: Correlations B... B').

15   Variants A and B relate to the ordinary cylinders. Variants A' and B' relate to the

specified rotor cylinders where the above-mentioned conditions (a) and (b) must

be observed.

The installation of the B-F-L-Ws at the whole rotor cylinder may be done

as general variant [as shown at Figs. 39, 40], or as an additional variant. As

20   additional (to the installation at the bearings) variant it may be done only if need

will be.

Before the B-F-L-Ws are to be installed at the whole (specified) cylinder, the limit of permissible vibration at the whole rotor cylinder must be known [it must be indicated in the technical documentation of this rotor cylinder or of the T-G-S, or must be determined within the preliminary tests with certain definition

5   how the vibrations at the whole rotor cylinder refer to the vibrations at its rotor bearings].

The installation and fixing of the B-F-L-Ws at the whole rotor cylinder is analogous to what must be done for the installation and fixing at the bearings. Here, the limitations of the mass, length, etc. of the B-F-L-Ws are analogous to

10   the installation at the bearings. Automation of the process of removal of vibrations at every cylinder as a whole and at the whole T-G-S is analogical to what must be done for the B-F-L-Ws to be installed and used at bearing-fulcrum. The specified rotor cylinders of the T-G-S as the fulcra of the whole rotor system are shown in Fig. 40. Every specified cylinder along the rotor system of the whole T-G-

15   S may be accepted as the bearings-fulcrum of the rotor system. Here, when the removal of vibrations is to be done at the specified cylinders, every zone of removal of vibration according to the B-F-L-Ws' method at the specified cylinder may be called *the bearings-fulcrum zone*; compare with *the bearing-fulcrum zone* (see also to compare: Fig. 1).

20   The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not

intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, to thereby enable others

5   skilled in the art to best utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents. Therefore, the scope of the invention is to be limited only by the following claims.

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